## PENETRATING RADIATION AT HIGH ALTITUDES.[1]

By W. KOLHÖRSTER.

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A series of experiments on the determination of the penetrating radiation present in the earth's atmosphere, have been made at various known altitudes above the earth's surface. The instrument used in measuring the ionisation was the author's modification (Sci. Abs., 1914, §888) of the Wulf type of electrometer. The following interesting table of results is given:

| Height above sea level. | Difference between the number of ions per cubic meter at the height considered and on the earth's surface. | |
|---|---|---|
| | 1913 | 1914 |
| *Meters.* | | |
| 1,000 | −1.5 | ..... |
| 2,000 | 1.2 | ..... |
| 3,000 | 4.0 | 4.3 |
| 4,000 | 8.3 | 9.3 |
| 5,000 | 16.5 | 17.2 |
| 6,000 | 28.7 | 28.7 |
| 7,000 | ..... | 44.2 |
| 8,000 | ..... | 61.3 |
| 9,000 | ..... | 80.4 |

Assuming the relation $I = I_0 e^{-\lambda d}$ for this radiation, the value of the absorption coefficient for air at atmospheric pressure is given as $1 \times 10^{-5}$ cm.$^{-1}$, whereas that of the $\gamma$-radiation from Radium C is $4.5 \times 10^{-5}$ cm.$^{-1}$. This radiation is therefore extremely hard, being only reduced in intensity by 1 per cent in a layer of air (at atmospheric pressure) 7 km. in thickness. It is shown in the above manner that a very penetrating radiation exists which has its origin somewhere in space, but by far the greater part is due to the sun.—*A. B. W[ood]*.

## AURORÆ, EARTH CURRENTS, AND MAGNETIC DISTURBANCES.[2]

By OTTO KLOTZ.

[Dated: Dominion Observatory, Ottawa, Canada, Oct. 23, 1915.]

[Auroræ, earth currents, and magnetic disturbances] may all be treated as a common subject or phenomenon. Let it be stated right at the outset that our ignorance of them is still vast.

The following dispatch from Winnipeg on June 17, 1915, is so interesting that it is inserted in full, besides giving an opportunity for explaining some of the statements made therein:

Aurora, more mysterious than wireless telegraphy, less constant than the visible manifestations of electrical storms, is to-day tangling up all the telegraph wires strung across the top of the continent, more especially those along the north shore of Lake Superior. There has not been such a complete tie-up in the telegraph business between eastern and western Canada for a long time, and possibly records for the month of June might be searched for many years back without finding a parallel. In fact, well-conducted auroræ confine themselves to the fall and winter months, and of all the months in the year June is most immune. The record of observations in Scandinavia and Iceland, as well as the Spitzbergen station, show no aurora at all in June, though on the North American Continent it is not unknown, though still a rare June phenomenon.

Aurora manifestations are almost entirely confined to night, and these manifestations, whether visible or not, are commonly accompanied by magnetic earth currents, and it is these properly that affect the wires. Usually with the morning sun the whole manifestation lifts, wires surcharged with excessive and variating currents are freed and released for their daily business, and the atmosphere, overloaded with electricity, becomes normal. But to-day the magnetic storm, potent though both unseen and unheard, is raging as furiously, to the tune of crackling wires at noon, as it was at midnight. The sky is heavy and overcast. When the clouds lift and the sun breaks through, the whole trouble will vanish magically as it came. For generations scientists have sought the secret of aurora and earth currents but have learned little beyond the central fact of the inconstancy of all available data on the subject.

Another peculiarity of the present visitation—a scourge alike to the telegraph companies and the daily newspapers—is that, whereas usually it is only wires running east and west that are affected by the polar visitant, on this occasion wires running north and south, such as those between Winnipeg and Minneapolis, are affected to nearly the same extent. From the meteorological point of view, this magnetic storm adds one more to the queer performances of the current month of June.

The first and natural question to occur to an observer beholding the aurora—a brilliant aurora with its dancing, shooting streamers; building, forming, and dissolving; rushing from its northern arch to meet beyond the zenith; clothed, perhaps, in greenish gauzy drapery, or yet in portentious red; ceaseless activity, a mysterious phenomenon, bewildering to mind and brain—is: What is the aurora? Beholding it gives no answer, but when we compare the phenomenon with associated ones we learn a little of its nature. We find it to be electric in its nature, an electric discharge. But here our positive knowledge about its nature stops.

We may mention the theories that have been advanced to account for the aurora. Birkeland regards the phenomenon as due to cathode rays emanating from the sun; Nordmann replaces the cathode rays by Hertzian waves; and Arrhenius supposes negatively charged particles to be sent out by the sun and reaching the earth, ionizing the upper regions of the atmosphere and thereby making it a good conductor for electrical discharges. The cathode rays we know travel at about a tenth of the velocity of light, hence would take nearly an hour and a half to reach us from the sun; the Hertzian waves at the velocity of light, i. e., 186,000 miles a second; and Arrhenius's particles would take about 46 hours, about two days for transmission. The transmission time forms an important factor when an attempt is made to associate particular sun spots and solar outbursts with particular auroræ and magnetic disturbances. The solar effect is that the discharge of the difference of potential on the earth is greatly facilitated; we have an electric current established with its consequent phenomena of auroræ, earth currents and magnetic disturbances. These are all more or less influenced by local conditions on or in the crust of the earth, and hence vary in intensity at different places. However, the strong currents encircle the earth, as we see in some notable cases, and manifest themselves particularly in magnetic disturbances and earth currents.

The electrical discharges, for of such are the auroræ, where do they take place? Many measurements and photographs (Störmer) have been made of the aurora to determine its position—height—in our atmosphere, and it has been found that the height, although varying considerably, is of the order of 50 miles. At that elevation the atmospheric pressure is only about 1/500 of an inch, about the pressure in a Geissler tube. The discharge of electricity through highly rarified gases and vapors in the large tubes, with the accompanying glow, at the Centennial Exposition in 1876, impressed the writer at the time with its close analogy and resemblance to the aurora or northern lights.

We may look upon the sun, not as the source of the magnetic disturbances, but as the medium that sets loose the bound energy residing in and on the earth.

[1] Deutsch. Phys. Gesell., Verh., July 30, 1914, 16, 14:719-721.
[2] *Reprinted from* Jour. Roy. Astron. Soc. of Canada, January, 1916, v. 10, No. 1, p. 8-14.

It will generally—although not always—be found that the center of the auroral arch, if there be one, is in the magnetic meridian. In eastern Canada and the eastern United States this will be west of the true or astronomic north, while west of Lake Superior to the Pacific it will be east of the true meridian. Furthermore, if the streamers ascend from the north toward the zenith or beyond it, it will be found that their focus or meeting place is beyond or south of the zenith, and at a point approximately where the direction of the dipping needle intersects the celestial vault. We see here then a pretty close connection between the aurora and compass and dipping needle, which we know otherwise to exist. It is fairly safe to say that there is never a bright auroral display without an accompanying magnetic storm, and [in support] many cases might be cited. The inverse of the statement—that with every magnetic storm we have auroral display—is not so obvious, because the magnetic instruments are always at work, being self-registering, independent of day or night, while the aurora is a matter of visibility, and hence observations are [confined] practically to the night. Here we may cite a most interesting case—that of the great auroral display and great magnetic storm of June 17, [1915] last. Prof. E. E. Barnard, in Nature of July 15, [1915], gives a vivid description of the aurora as seen at the Yerkes Observatory.[3] The maximum brilliancy was reached shortly after 2 a. m., central standard time [90th mer. time], and shortly afterward dawn blotted out further observation. While the aurora was pursuing its magic performances in the heavens the magnetic instruments all over the world were mightily perturbed, and as we know from the Winnipeg dispatch quoted and other press reports, the telegraph lines were more or less demoralized by the atmospheric electric currents. While dawn was breaking with us, night was approaching in New Zealand, so that this world-encircling phenomenon could be observed there after daylight had made it invisible in America. And this is what happened. While it was midsummer with us, it was midwinter at Dunedin, latitude 46° S., longitude 170° 30′ E., or $11^h\ 22^m$ ahead of Greenwich, and the sun set before 5 p. m. Standard time in New Zealand is fast on central standard time $17^h\ 30^m$, so that 2 a. m. quoted by Barnard would be $19^h\ 30^m$ or 7:30 p. m. in New Zealand.

Mr. W. E. McAdam, of Dunedin, writes:

> Upon that day (June 17) there was an exceptionally fine display of the Aurora Australis visible all over New Zealand. Here, at Dunedin, it commenced at 7:30 p. m. and lasted till midnight. The glow in the southern horizon was quite uncanny in effect, producing the illusion that the sun was about to rise in an impossible quarter of the sky, and at an impossible hour. I have been resident in the Southern Hemisphere off and on for 50 years, and have never seen anything to equal the last display of the Aurora Australis, a somewhat rare phenomenon, in the latitude of Dunedin, 46° S.—(Nature, Sept. 30, 1915.)

This is a most interesting case, showing that while the "movies" became invisible in Canada, the night of New Zealand revealed their continued presence.

The aurora does not distribute its favors equally over the earth. The Tropics and semi-Tropics are practically devoid of them. The curves of equal frequency dip considerably farther south in America than in Europe. No country is so favored by this ethereal visitant as is Canada. From what has been said it is obvious that more auroræ will be seen and are seen during the winter months than during those of summer, simply because in the former case the nights are longer and consequently [increase our chances of seeing] the aurora, if there is one.

[3] See also this REVIEW, November, 1915, p. 546; September, 1915, p. 445.—C. A. jr.

The aurora has often the appearance of filaments or streaks of clouds, but the distinction is readily observed by the presence of a star or stars behind; for the transparency of the former dims but little, if any, the brightness of the star, which by the latter, even if filmy, would be more or less obliterated.

In tabulating sun spots and the frequency of auroræ over a long period of years, it is found that there is a very general agreement between the maxima of the one and the maxima of the other, and similarly between the minima, but the definite relationship between the two is not known. Auroræ, magnetic disturbances and earth currents are simultaneous phenomena due to electric currents in the higher regions of the atmosphere. Their individual intensity is to a degree dependent on local conditions, such as difference in geological formations, and all follow in a general way the sun-spot cycle of 11 years.

In examining the spectrum of the aurora it is found that there is one rather prominent line in the yellow-green, wave-length 5571$\mu$, which coincides with a prominent line in the sprectrum of krypton.

The writer has seen many auroræ in our Northwest, their home, and has conversed with Hudson Bay Co. officers and voyageurs from whom information is said to have been obtained that noises have been heard during auroral displays, and [whose statements have] been quoted in books and articles on the subject; yet the writer is convinced that there is no authentic record of any noise ever having been heard, although subjectively the "noises" may have been *felt*, as was the case, I am sure, with Ogilvie's man.[4]

The interference of earth currents with the working of telegraph and cable lines is largely overcome by making a metallic circuit and, thereby, cutting out the earth. This, of course, reduces the capacity of the service.

Prof. Barnard reports that signals on June 17, during the aurora display, on the wireless receiver at the observatory were not affected, and that the static conditions were normal.

With reference to earth currents and cables, the writer may be permitted to quote extracts from his official report in 1892, in connection with the trans-Atlantic determination of longitude. At that time there were 10 cables across the Atlantic, but when earth currents set in they were not all equally disturbed, in fact, sometimes some of the cables not at all.

> The French cable from Brest to St. Pierre seems to be disturbed the most, and again the disturbances are felt to a greater extent at St. Pierre than at Brest. It often happens that St. Pierre can send messages to Brest but can not receive any. Long cables seem to be more affected than short ones, and, furthermore, the earth currents appear to travel mostly from east to west. When the aurora is visible it is pretty certain that earth currents will show themselves. Thunderstorms and [earth currents?] however, do not seem to be so closely related, if at all. During the past season (1892), on July 16, there was a remarkable disturbance noticed at Canso, stopping all work completely. The greatest "kick," as it is called, was given at 12:20 p. m., E. S. T., or 5:20 G. M. T. Some weeks afterward reports came in the technical journals, from Brest, Malta, Cairo, Madras, and east to Singapore, of a similar disturbance on that day. Cairo, Egypt, fortunately stated the time, and from it it was found to have been simultaneous with that of Canso. On August 24 (1892) strong earth currents set in at Canso, and at the time there was a marked auroral display. The southern cable (Commerical Co.) was far more affected than the northern one. As most of the companies have two cables they can generally get rid of the effects of earth currents by looping the cables together—that is, by making a metallic circuit. Sometimes the earth currents are so strong as to injure the condensers. From the direction of the cables it is noticed that cables running east and west are more troubled with these currents than cables running north and south. There is, however, a wide difference on east and west lines. The superintendent at St. Pierre told me

[4] *See* J. Oxall in this REVIEW, Jan., 1914, 42: 27-29.

that he experienced more earth currents in the past 2 years (1891, 1892) at that place than in the preceding 18 years at Torbay and Canso, N. S., and beside that they are felt more on the American than on the European side. And furthermore:

"The cable is quite unprejudiced and shows equal favor to positive or negative gallantries. They are of the most erratic nature; sometimes they take off their things and make quite a visit, 1, 2, or 3 days, varying greatly in their demonstrativeness during the time, but seldom getting so bad as to totally stop traffic. Sometimes they favor us with a 2 or 3 minute call only, as if to remind us that they are still alive. They fluctuate in degree very greatly. The strength or electromotive force of these earth currents has run up to 500 volts."

We have now said considerable about the subject of this paper, yet have, undoubtedly, failed to answer all the questions of the "practical" man. The practical man wants the aurora, earth currents, and magnetic disturbances stopped, for they interfere with his work; the scientist doesn't want them stopped for they are a stepping stone leading upward toward unraveling the grand mechanism of nature. All life, all activity, all energy of the earth we may trace back to the sun, and until his secrets are revealed we shall remain in ignorance of much that is going on on our globe. At present our hopes are specially centered on Mount Wilson, where Prof. Hale and his assistants are bending all their energies upon our central orb. They intercept every messenger coming from the sun and put him through a rigorous examination—what his business is and what dispatches were intrusted to him before he left home. All these dispatches are written in hieroglyphs, and only for a few, as yet, has a Rosetta stone been found for their interpretation. No gained ground is ever lost by the scientist; he is ever on the offensive. Of the messengers sent out by the sun, the earth intercepts but a very small portion; less than one two-thousand-millionth.

Until some of these messengers have been made to reveal their secrets we can only conjecture as to the why of the aurora, earth currents, and magnetic disturbances.